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UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. KRUG, SECRETARY

BUREAU OF MINES
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# ELECTRIC BLASTING SWITCHES, UNDERGROUND MINES, LAKE SUPERIOR DISTRICT

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BY

MAX S. PETERSEN AND FRANK E. CASH

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UNITED STATES DEPARTMENT OF THE INTERIOR — BUREAU OF MINES

# ELECTRIC BLASTING SWITCHES UNDERGROUND MINES — LAKE SUPERIOR DISTRICT[1/]

By Max S. Petersen[2/] and Frank E. Cash[3/]

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## INTRODUCTION

Explosives have been used in ever-increasing amounts since gunpowder was invented. For hundreds of years only low explosives of the deflagrating

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1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote is used: "Reprinted from Bureau of Mines Information Circular 7372."

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type were used, and they were fired by means of a flame or hot object. Benjamin Franklin first ignited gunpowder from a distance in 1751 by means of an electrostatic spark. Further efforts to develop a satisfactory electrical method to ignite explosives from greater distances were overshadowed by the invention of safety fuse in 1831, as this offered a relatively simple and inexpensive means of firing explosives.

The discovery and introduction of high explosives of the detonating type and the invention of the fulminate of mercury blasting cap about the middle of the nineteenth century provided the needed impetus for inventors to develop means of firing the cap by electricity. The original high-tension igniter, following Benjamin Franklin's experiment in which the detonating compound was ignited by a spark, was discarded in favor of a low-tension igniter, in which the detonating compound was ignited by a heated wire. The past 2 decades have seen considerable improvement in the design and construction of electric detonators to make them safer and more efficient, yet in spite of the improvement it is estimated that less than 50 percent of the explosives used in industry today are ignited or detonated electrically. The trend, however, is toward the use of electric methods. In recent years numerous mining companies have introduced electric blasting exclusively at their mines as a means of improving safety and efficiency.

The Federal Bureau of Mines for many years has advocated the use of electric methods of detonating explosives, because the Bureau believes it is the safest method when properly conducted. This belief is shared by most explosives manufacturers, who in their handbooks recommend electric blasting under difficult conditions, such as driving long raises, shaft sinking, station cutting, and in workings in wet places. In some instances, state laws require the use of electric blasting under the conditions previously mentioned. In coal mining, where the additional hazards of explosive gas and dust exist, electric blasting is a requirement for the proper use of permissible explosives. A study of explosives accidents in the Pennsylvania anthracite region[4/] covering a 5-year period tends to justify the Bureau's stand. This study reveals an accident rate of 1.9 per million holes fired electrically against a rate of 2.9 when fuse and caps were used.

Today with the keen interest in safety and the tendency toward larger rounds of blast holes, electric blasting is becoming increasingly important.

A study of electric blasting practices in the Lake Superior region reveals that the blasting procedures and equipment in use, although similar, are not standard, even in mines operated by the same company. One factor contributing to this condition is that suitable electric switches are not manufactured, and each local electrical department is forced to assemble and remodel existent switches or build its own switches to fit the particular requirements. As a result, several operating companies have developed their own designs and arrangements of switches.

4/ Howell, S. P., Rept. of Investigations 2986, 1930, 13 pp. Experience with Electrical and Other Means of Firing Shots of Explosives in the Anthracite Region of Pennsylvania.



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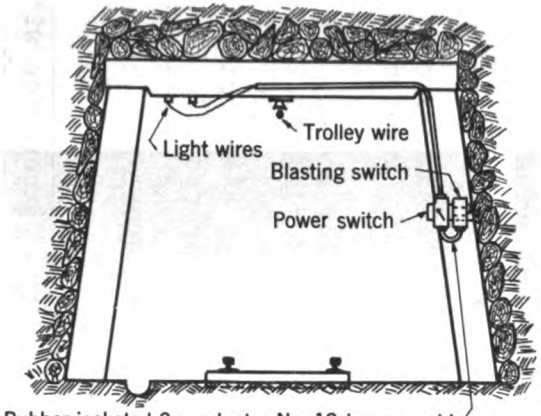



Rubber-jacketed 2-conductor No. 12 jumper cable, equipped with special plugs. Removed after blasting and carried by person supervising charging and blasting

Power switch--25A-250V.--2P. Delon circuit breaker with receptacle for jumper cable with spring return to "open" position.

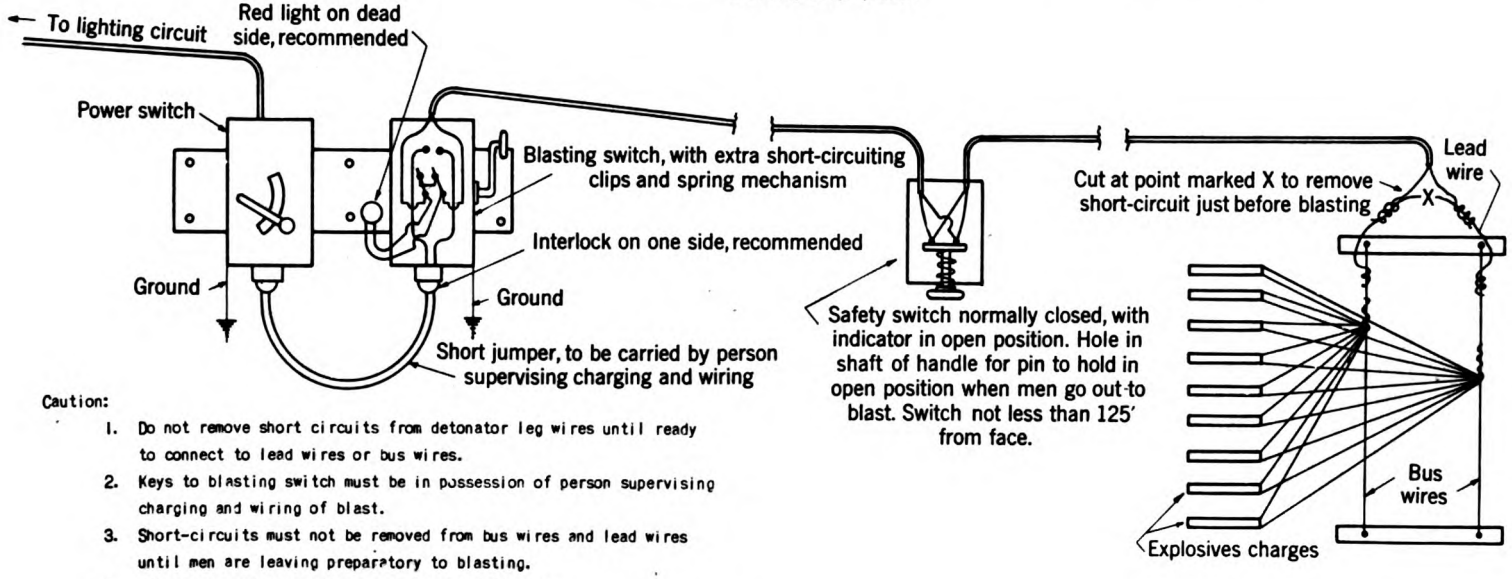
Blasting switch--60A.-250V.--2P.--S.T. non-fusible safety switch. Remodeled to provide 2 extra clips mounted on an insulating support so that the blades will transfer automatically into these clips when the handle is released. These clips to be short-circuited by a jumper. Operating mechanism to be held in "open" or short-circuited position by means of a spring return added to switch. Switch also to be locked in "open" position.

Safety switch--Single-pole, normally closed switch with spring mechanism to hold switch in closed position. Hole in shaft of handle for pin to hold in "open" position when men go to blast. Switch may also be locked in "closed" position.

Blasting line--Not less than #12 2-conductor or 2 single-conductor, rubber-jacketed cable suspended on insulators on opposite side of drift from light and power lines.

Lead wires--Not less than #14 single conductor, rubber covered.

Bus wires--Not less than #16 (not ordinarily required, but may be necessary when blasting large round.)


To lighting circuit
Red light on dead side, recommended
Power switch
Blasting switch, with extra short-circuiting clips and spring mechanism
Interlock on one side, recommended
Ground
Ground
Short jumper, to be carried by person supervising charging and wiring
Safety switch normally closed, with indicator in open position. Hole in shaft of handle for pin to hold in open position when men go out to blast. Switch not less than 125' from face.
Cut at point marked X to remove short-circuit just before blasting
Lead wire
X
Bus wires
Explosives charges

Caution:

1. Do not remove short circuits from detonator leg wires until ready to connect to lead wires or bus wires.
2. Keys to blasting switch must be in possession of person supervising charging and wiring of blast.
3. Short-circuits must not be removed from bus wires and lead wires until men are leaving preparatory to blasting.
4. All electrical connections must be carefully made.
5. Cross-bonding of rails and pipe lines to be not more than 100' from face. Tugger frames to be electrically bonded. Should be tested for voltage differentials when bonds are moved forward.

**Figure 1. - Switch and wiring diagram -- Company A.**

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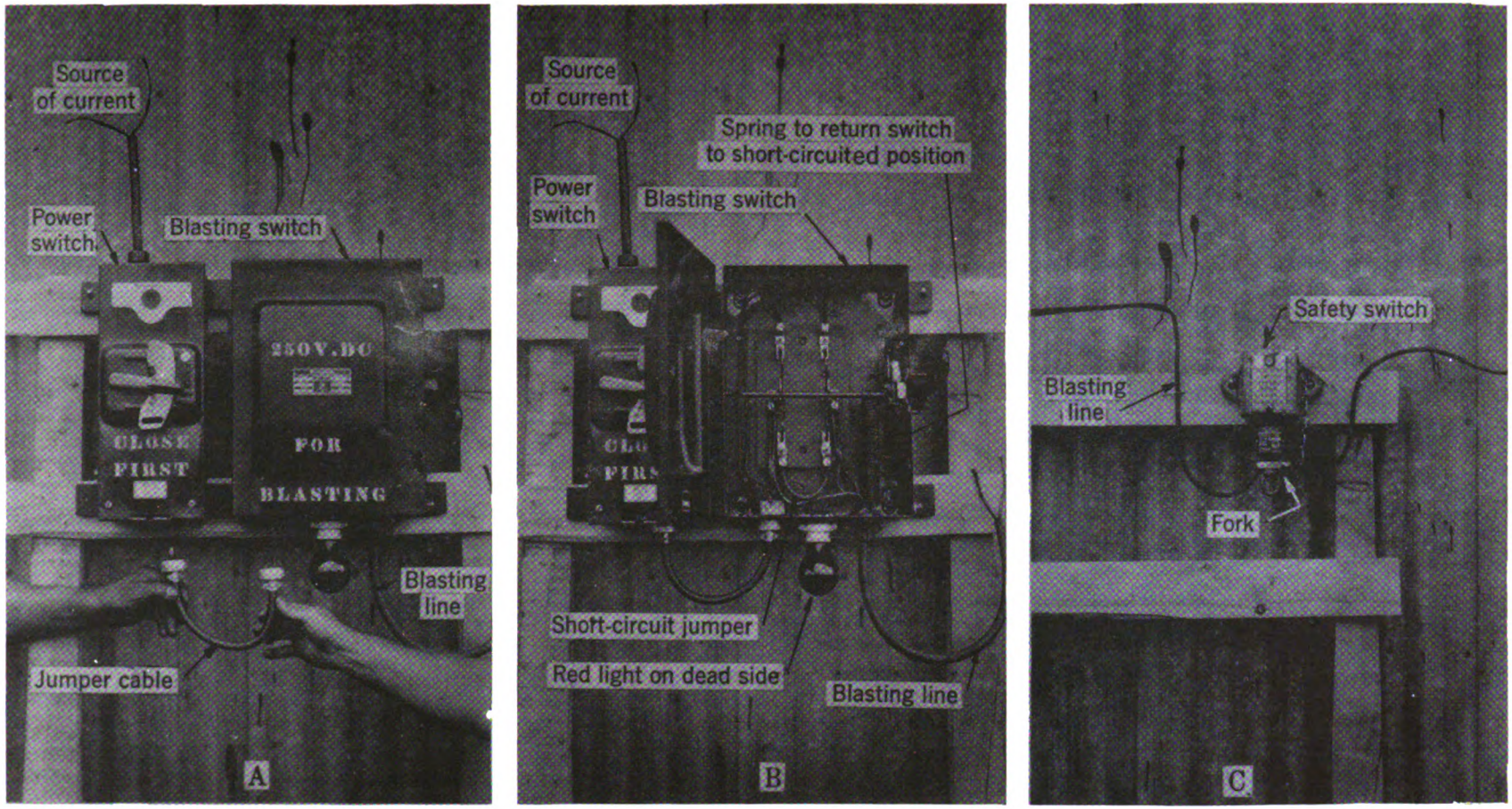


Figure 2. - Details of switches for electric blasting -- Company A: A, Power and blasting-switch unit; B, blasting switch (open); C, safety switch.

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## SCOPE

This report describes six electric-blasting-switch arrangements in use by three large iron-ore mining companies in the Lake Superior district. It is hoped that descriptions of these arrangements, which are a result of considerable thought and effort on the part of the mining companies, will enable other operators to benefit by their experience. The report covers blasting from power lines only.

## ACKNOWLEDGMENTS

Appreciation is expressed for the cooperation of the officials of the various mining companies who permitted their electric blasting equipment to be photographed and blasting procedures to be observed.

## COMPANY A

### Electric Blasting Equipment

The recommendations issued by the safety department of Company A for electric blasting are embodied in the switch and wiring diagram shown in figure 1. Minor changes and modifications may be made to suit the local conditions at the mine after such change or modification is approved by the safety department.

The blasting equipment and procedures used at a typical mine, using 250-volt direct current, operated by Company A follows:

The power switch (figs. 1 and 2, A) is a 25-ampere, 250-volt circuit breaker. It is equipped with a receptacle to receive the jumper cable connecting it to the blasting switch. The function of the power switch is to protect the power source against possible short circuits.

The blasting switch (figs. 1 and 2, B) is a 60-ampere, 250-volt, 2-pole, double-throw, nonfusible safety switch. The double-throw switch is used instead of the single-throw type recommended in figure 1 because the lower set of contacts can be short-circuited and used instead of the extra clips mounted on an insulating support, as recommended. The blasting switch is equipped with a receptacle to receive the jumper cable from the power switch and is provided with a spring to return the switch blades automatically to the short-circuited position. A red light, mounted on the bottom of the switch box and connected to the dead side, indicates the flow of current to the blast when the switches are closed.

The blasting switch is locked in the "open" position at all times except during blasting.

The safety switch (fig. 2, C) is a single-pole, mine-signaltype switch, which is closed in the normal position; its purpose is to provide a short circuit across the blasting leads at a distance of not less than 125 feet from the blast. The short circuit is removed by pulling the handle of the switch down and inserting a fork between the switch body and the collar on the pull shaft. A fork is used in this instance instead of a pin, as recommended in figure 1.



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The switch housings of the power switch and the blasting switch are grounded; the safety switch is not grounded.

### Blasting Procedure

The person supervising the charging and wiring of the blast carries the key to the blasting switch and the short jumper cable used to connect the power switch to the blasting switch. The leg wires of the detonators are connected in parallel, as indicated in figure 1, although the bus wires shown are seldom necessary. The usual practice is to twist detonator leg wires of the same color together and attach them to the lead wires with connecting wire. After all connections are made at the face, the miners retire to the safety switch. The handle of the safety switch is then pulled down and the fork inserted, which holds the switch in the "open" position. This removes the short circuit and makes the blasting line continuous back to the blasting switch, where the leads are still short-circuited. Upon reaching the blasting switch, the person supervising the blasting inserts the jumper cable between the power switch and blasting switch, sets the circuit breaker, and unlocks and closes the blasting switch. This completes the circuit to the charges.

In figure 3, A shows the circuit breaker being set, and B shows the blasting switch closed.

## COMPANY B

### Electric Blasting Equipment

Wiring diagrams of three combinations of switches used by Company B for electric blasting are shown in figure 4.

The arrangement shown in figure 4, A, is used where shelter is nearby, and the lead wires to the blast are relatively short. In this instance, a "safety switch" between the charge and the point from which the blast is fired is considered unnecessary.

Where shelter from the blast is a considerable distance away, the arrangement shown in figure 4, B, is used. This involves a magnetic switch in addition to the switches used in arrangement A. Arrangement C shows a variation of arrangement B, where the distance and size of conductors involve such a voltage drop that the magnetic switch does not operate. In this instance, a separate pair of conductors is installed to operate the coil of the magnetic switch.

A 4,000-foot drift has been completed recently at one mine operated by Company B, which uses the arrangement shown in figure 4, B. A description of the equipment provided and the procedures used follows:

Figure 5 shows the three switches used in the blasting circuit, as follows: the main switch, the manual blasting switch, and the magnetic blasting switch. The main switch and the manual blasting switch constitute the unit, which is mounted on a wooden panel at the point from where the blast is fired. These two switches are mounted at least 3 feet apart to provide an



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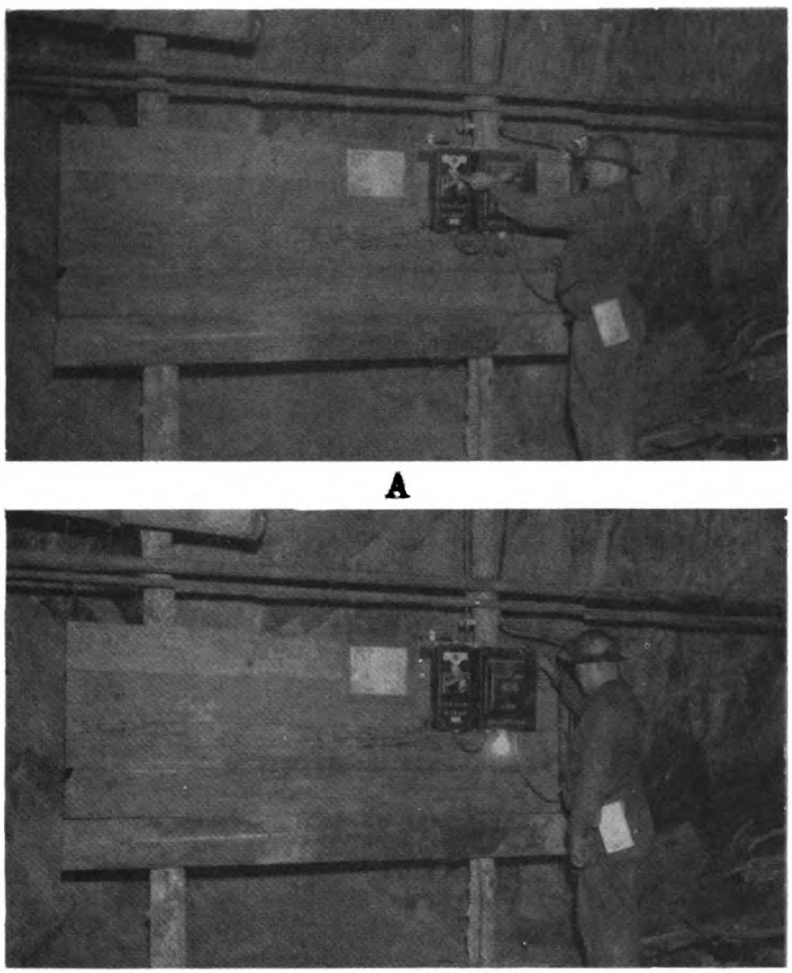

A

B

Figure 3. - Firing blast -- Company A: A, Setting power switch; B, blasting switch closed.

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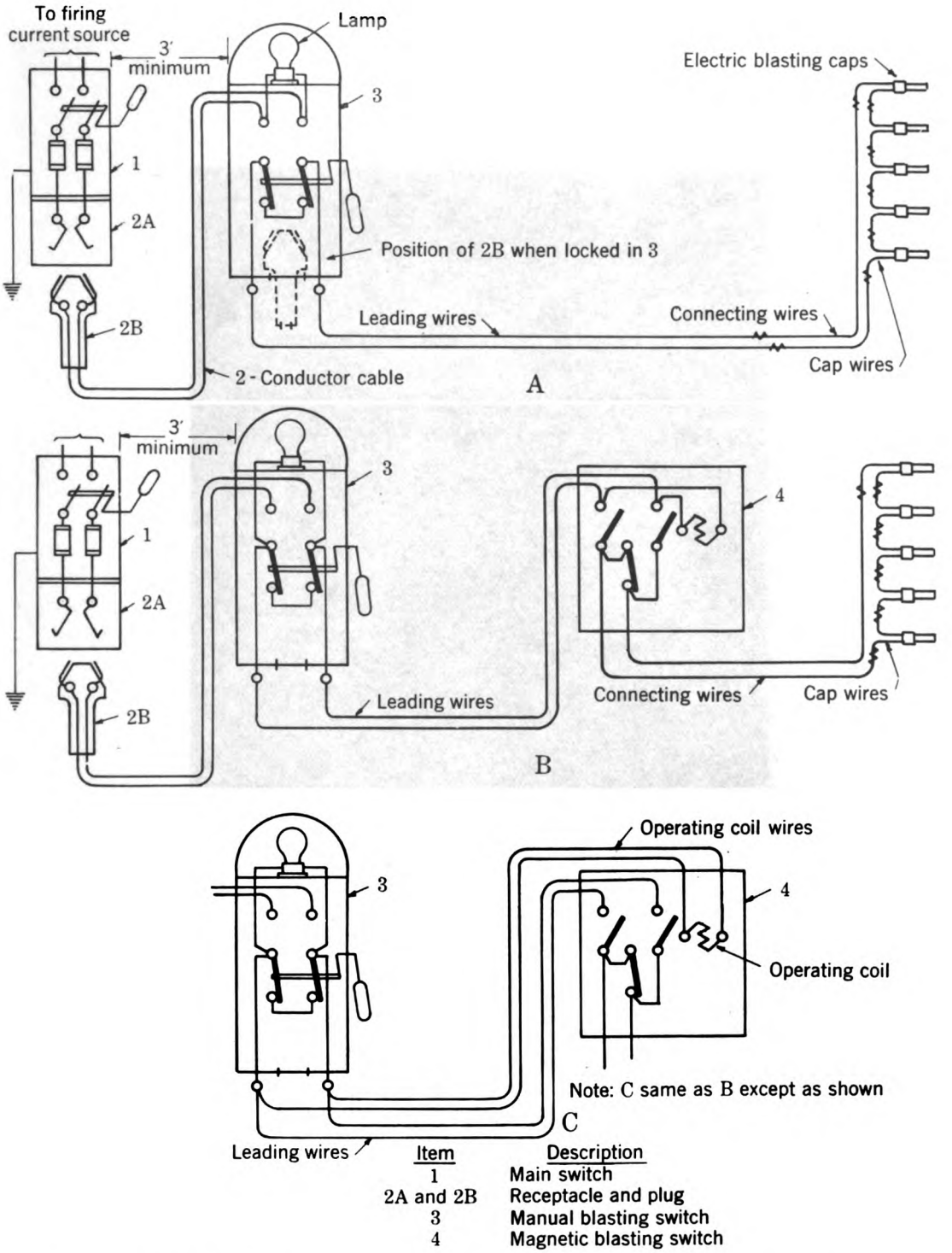


| Item | Description |
|---|---|
| 1 | Main switch |
| 2A and 2B | Receptacle and plug |
| 3 | Manual blasting switch |
| 4 | Magnetic blasting switch |

**Figure 4. - Switch and wiring diagram -- Company B: A, Where shelter is near by; B, for long drifts or raises; C, for long distances involving voltage drop.**

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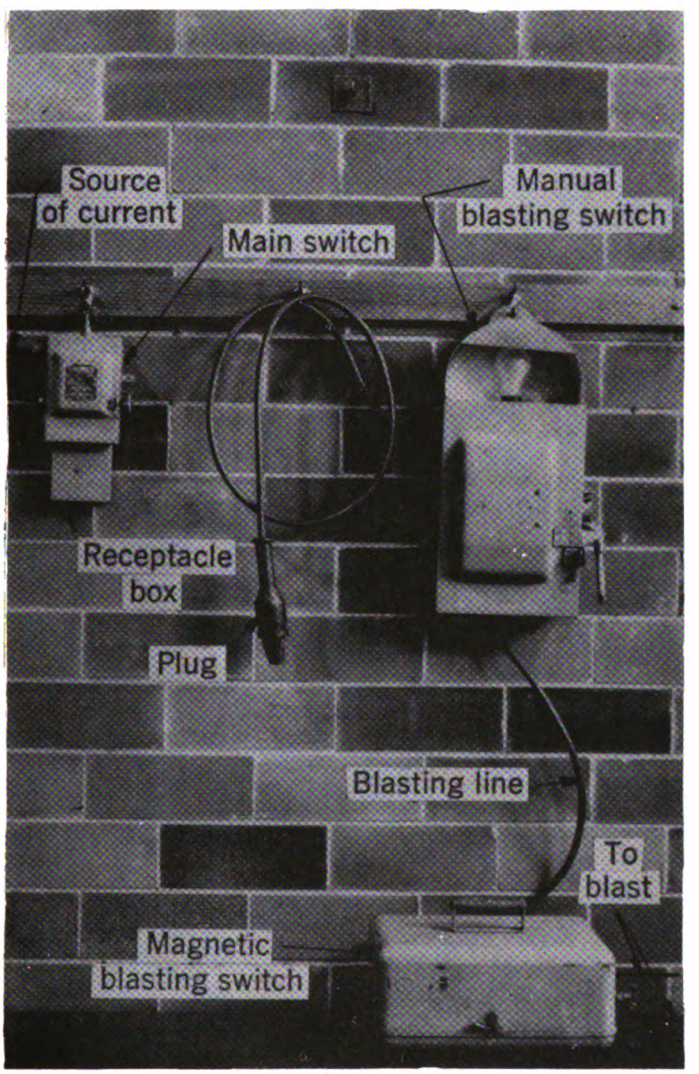


Figure 5. - Blasting-switch assembly -- Company B.

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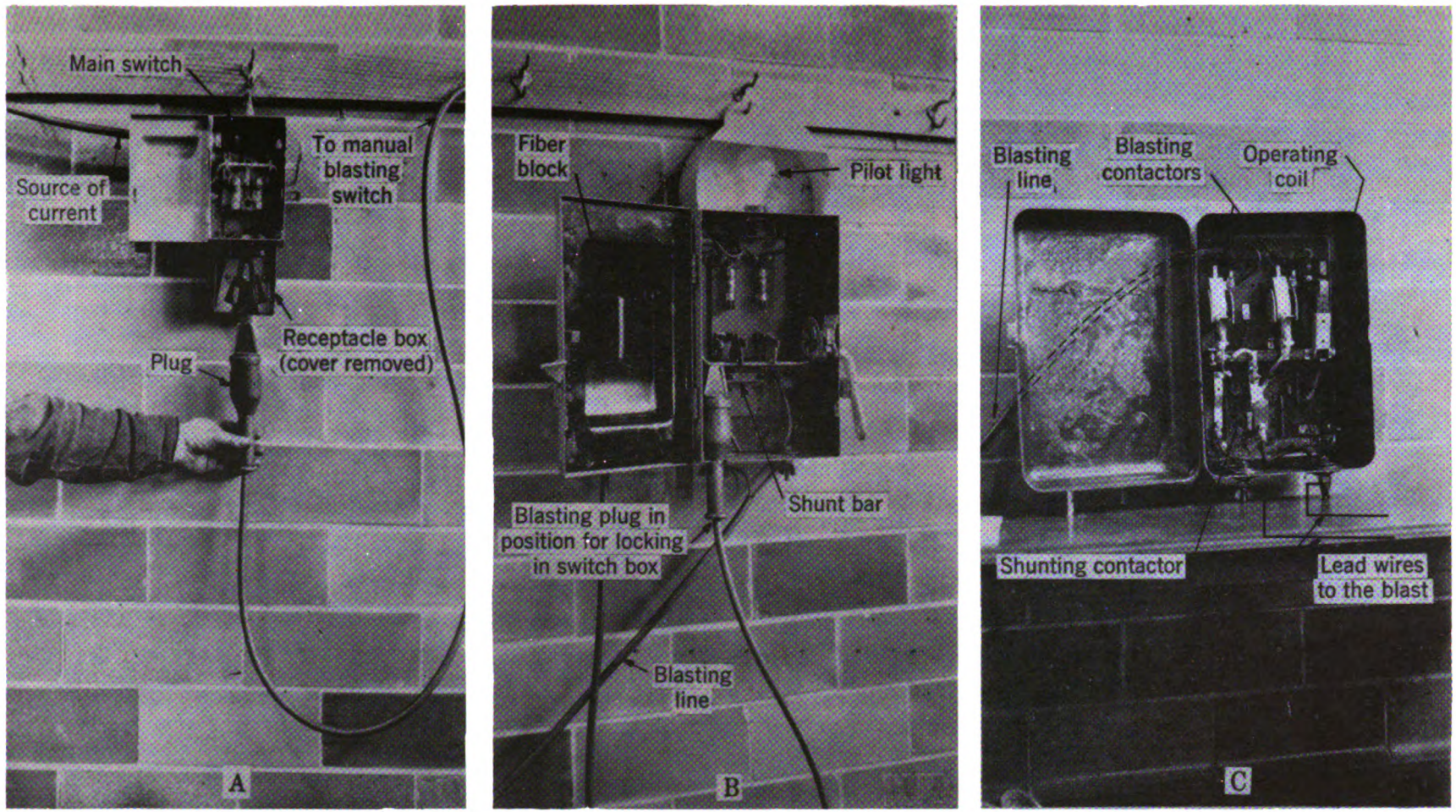


Figure 6. - Details of switches for electric blasting -- Company B: A, Main switch; B, manual blasting switch; C, magnetic blasting switch.

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interruption gap for protection against high potential current, such as lightning. The magnetic blasting switch is installed as near the blast as feasible and is protected from flying rock by planks or a "turtle box." The main-switch housing is grounded. The manual-blasting switch is not grounded, nor are any grounds permitted between the main switch and the face to be blasted.

Details of the three switches are shown in figure 6. The main switch, shown in A, is a 30-ampere, 250-volt, 2-pole, single-throw, fused safety switch to which a blasting-plug-receptacle box has been attached. The receptacle is made in the local shops from two controller fingers and a metal box, suitably insulated. The blasting plug, which fits into the receptacle, consists of two controller segments and a wooden filler in a Protex rubber handle.

The manual blasting switch is shown in figure 6, B. It is a 30-ampere, 250-volt, 2-pole, double-throw, safety switch without fuses. (The switch pictured is a fused-equipped type, but the fuses are "plugged".) A shunt bar is attached across the lower set of contacts, which provides a short circuit across the lead wires to the blast when the switch is in the lower position. To assure that the switch is in the lower position, except during blasting, a fiber block, attached to the door of the switch, bumps against the switch-operating rod and prevents the switch from being closed and locked.

Two features prevent the switch from being closed prematurely: (1) The switch handle is locked in the "off" or short-circuited position, and (2) the interior locking mechanism of the switch handle has been altered so that the handle itself cannot be moved until the door of the switch is opened. Obviously, the effectiveness of these features depends primarily upon use of the padlock.

A notch in the bottom of the switch box receives the blasting plug, which is locked in the box, except when the blast is to be fired. A pilot lamp is provided in an open cave above the switch. It may be connected in one of two ways, as indicated in figures 4, A, and 4, B.

The magnetic blasting switch is shown in figure 6, C. It is a 3-phase, alternating-current, magnetic starter, from which the heater relays and coil interlocks have been removed. The center set of stationary and moving contact members has been shifted 180° about the operating shaft and modified so that it is in the closed position when the remaining two (outside) members are in the open position. Thus, by connecting the wires of the blasting circuit, as shown in figure 4, B and 4, C, closing the center set of contacts short-circuits the wires leading to the charges. When the current is applied during blasting, the operating coil causes the short-circuiting contactor to be opened and the other two contactors to be closed. This removes the short circuit and completes the circuit to the blast. The magnetic blasting switch is maintained in a horizontal position as shown in figure 5. Under these conditions the short circuit is maintained, and the blasting circuit is kept open by gravity as well as by a spring installed for this purpose. Two wing nuts have been added to provide easy attachment of the wires from the blast.



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## Blasting Procedure

Company instructions issued for operation of the equipment are quoted below:

Before making any connections to blasting caps, the blaster makes sure that:

1. The main switch is open.

2. The manual blasting switch is in the short-circuited position, the plug is placed in the manual blasting switch box, and the manual blasting switch door is locked shut.

3. The magnetic blasting-switch contacts work freely and the short-circuiting contact makes good contact.

4. Then, after checking the above points and making all of his connections to blasting caps, he checks the insulation of all connections.

After all connections are made and he is ready to fire and all the men have found shelter, the blaster:

1. Unlocks the manual blasting switch and closes it in the blasting position.

2. Closes the main switch.

3. Inserts the plug in the receptacle.

4. After the blast is fired, he places the equipment in the positions noted under 1 and 2 of "Before making any connections to blasting caps."

## COMPANY C

## Electric Blasting Equipment and Procedure

A switch and wiring diagram of a set of switches used by Company C for electric blasting are shown in figure 7, A,[5] a brief description of which follows:

Switch (1) is a 30-ampere, 110-volt, 2-pole, single-throw, fusible safety switch, which is locked in the "open" position at all times except during blasting. The switch housing is grounded. Item (2) is a wooden cabinet about 12 by 18 by 4 inches deep, which is provided with two sets of

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5/ Trengove, Stanley A. (Asst. Supt., Hibbing-Chisholm District) and Pickering, Hayden M. (Pit Foreman, Hull-Rust Mine, Oliver Iron Mining Co., Hibbing, Minn.), Drilling and Blasting Practices: Proc. 18th Mine Safety Conference, Lake Superior Mining Section, National Safety Council.



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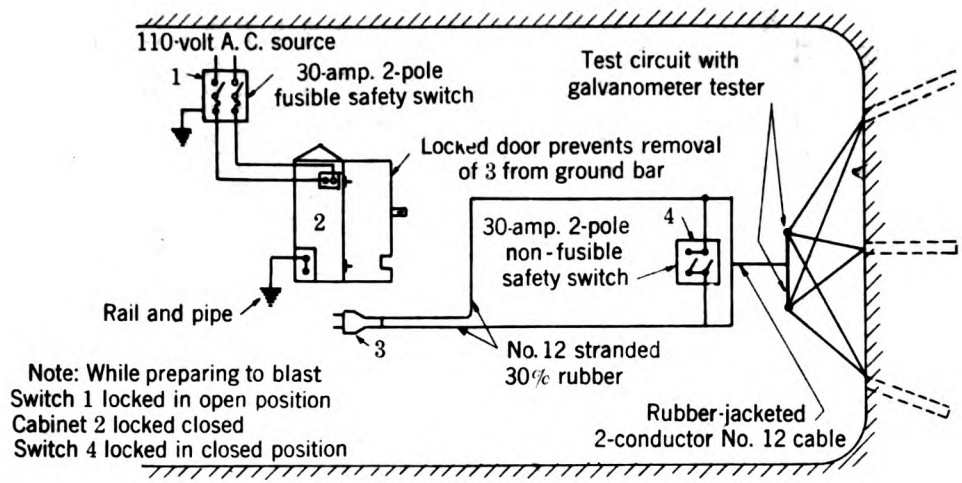
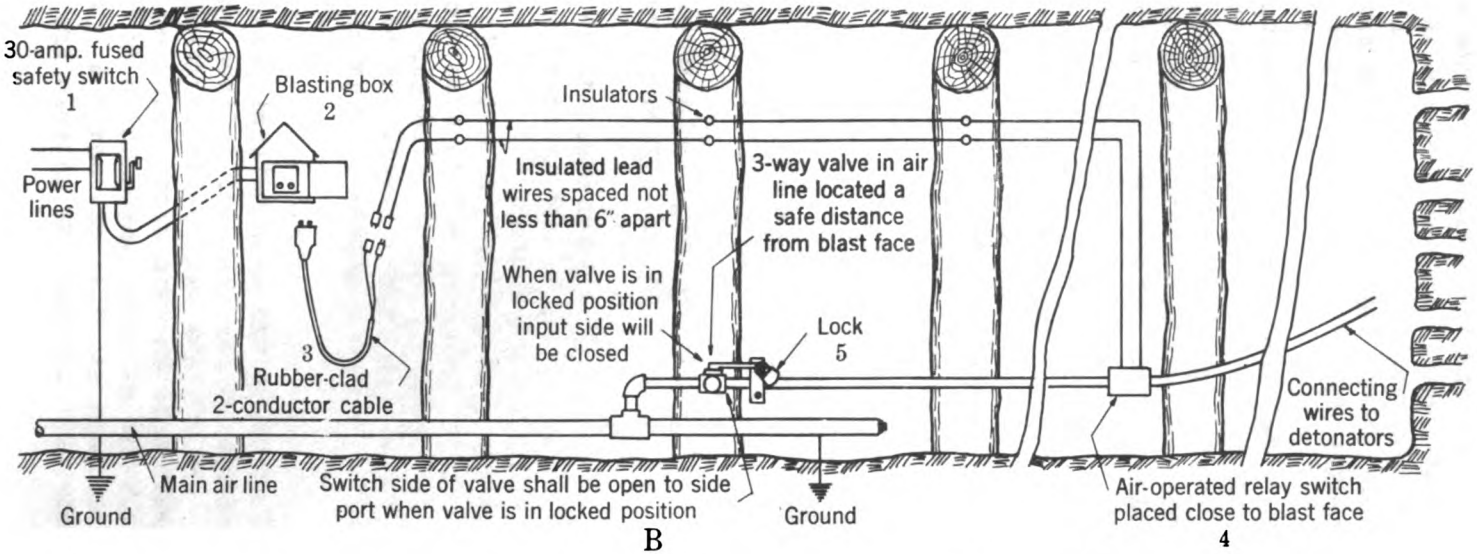



Connections for blasting with electric power

A




B

Figure 7. - Switch and wiring diagram -- Company C: A, Conventional method; B, using air-operated relay switch.



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shallow female contacts. The upper set of contacts is connected to the dead side of switch (1), and the lower pair is short-circuited and grounded. A wooden door closes over both sets of contacts and is locked, except during blasting. Item (3) is a wooden blasting handle provided with two male contact plugs, which fit the female contacts in the wooden box. When not in actual use, this blasting handle is placed in a compartment in the wooden cabinet, with the contacts against the set of short-circuited and grounded contacts. The compartment and handle are so constructed that the door will not close and lock unless the blasting handle contacts are properly placed against the grounding contacts. Item (4) is a 30-ampere, 2-pole, single-throw, nonfusible safety switch, the function of which is to short-circuit the wires leading to the blast, at a safe distance from the blast. The switch is normally locked in the "closed" or "short-circuited" position.

The sequence of switch operations to set off a blast is:

1. Unlock and open short-circuiting switch (4) upon retiring from the face.

2. Unlock and close main switch (1).

3. Unlock cabinet, and remove blasting handle from grounding contacts. the blast is fired by making a momentary contact of the male contact plugs of the firing handle to the live contacts in the cabinet.

A variation in the arrangement of switches for electric blasting, used to a limited extent by Company C, is shown in figure 7, B.[6]

Item (1) is identical to the switch of the same number in figure 7, A. Item (2) is a locked wooden blasting box containing two shallow female contacts connected to the dead side of switch (1). Item (3) is an 8-foot section of rubber-clad two-conductor cable, one end of which is provided with two male contact plugs to fit the shallow female contacts of the blasting box, the other end of which is fitted with a plug and a receptacle, to fit companion connectors attached to the wires leading to the blast. This permits the lead wires to be attached to each other, thereby providing a short circuit at all times except when the blast is fired.

Item (4) is an air-operated relay switch located near the blast to be fired and may be installed behind a cap or post of the last set of timber, within 5 feet of the face. It is a piston-type, oil-filled switch, so constructed that when it is in an "open" position, both sets of leads are short-circuited. The switch is connected to a three-way valve in the air line located at a safe distance from the blast. A three-way valve is used to prevent air leaks from building up pressure and closing the switch. The valve is locked in a "closed" position.

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6/ Jones, William (Safety Inspector, Oliver Iron Mining Co., Vermilion District, Ely, Minn.), Eliminating the Hazards of Stray Currents in Electric Blasting Proc. 20th Mine Safety Conference, Lake Superior Mining Section, National Safety Council, June 1943, pp. 56 to 62.



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The sequence of operations in blasting is:

1. Connect detonators to air-operated relay switch.

2. Unlock and open three-way valve, which operates the air-relay switch removing the short circuit and establishing a connection between blasting line and connecting wire to the detonators.

3. Unlock and close switch (1).

4. Connect section of cable (3) to blasting line.

5. Make a momentary contact between firing-handle contacts and the female contacts in the cabinet.

The use of an air-operated relay switch is an innovation in electric blasting in this region. It is an attempt to eliminate the hazard of stray currents setting off a blast at the time the detonators are connected to the blasting line or at the time the short-circuiting switch near the face is opened. The use of this air-operated switch permits the miners to remove the short circuit and complete the circuit to the blast by remote control from a safe place.

Details of the air-operated switch are not available; it was locally designed and constructed in the mine shop. The cost of constructing the original switch is estimated to exceed $100.00, but it is believed that it could be built in the mine shops for $35.00 to $40.00. If made in quantities by a manufacturer, the cost would be about $15.00. The use of such a switch involves laying an extra air line from the three-way valve to the switch. These features, with the difficulty of manufacture during war time, have limited its use somewhat.

## ADVANTAGES OF ELECTRIC BLASTING

A consideration of the advantages and disadvantages of electric blasting is necessary in order to weigh and evaluate the safety features of the various switch arrangements described. It is quite generally recognized that electric blasting requires more training than does the use of fuse and caps, but experience has proved that most miners can be trained to do the job by means of suitable safety rules, properly enforced.

Assuming that electric blasting is conducted properly, the following benefits are realized:

1. There is complete control over the moment of blasting, allowing all persons ample time to retreat to a place of safety, thus eliminating accidents occurring due to men overstaying the safe time limit when lighting fuses.

2. The number of misfires is reduced, and the firing order or rotation of holes is more positive, especially in wet places. This increases the efficiency of blasting.



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3. Hangfires, due to smoldering fuse, are eliminated.

4. Smoke and gas from burning fuse are eliminated.

5. The fire hazard is reduced.

As with most safety devices or practices adopted, electric blasting introduces new hazards, the most important of which are:

1. Possible premature application of the firing current.

2. Premature explosion caused by stray currents.

It is largely in an effort to overcome these new hazards that the previously described switch assemblies were designed.

Features of these assemblies intended to prevent a possible premature application of the blasting current are: Locked switches and the various gaps in the blasting circuit.

Protection against a premature explosion from stray currents includes: Gaps in the blasting circuit, properly insulated lead wires, short-circuiting of the lead wires, and grounding. Protection against stray currents, however, involves much more than the blasting equipment itself. Stray currents must be further minimized by bonding, interbonding, and proper selection, installation, and maintenance of all electrical equipment in the near vicinity.

## SUMMARY AND CONCLUSIONS

A summary and comparison of the six electric blasting switch assemblies previously described reveals similarities, advantages, and disadvantages of each.

Each assembly is composed of three main parts: (1) A device for protection of the power source against overcurrents; (2) blasting switch, usually mounted near such device and incorporating a break or gap in the blasting circuit; and (3) a "safety switch" installed in the blasting circuit at a point safely situated from the blast.

Of the six assemblies, five provide protection of the power source against overcurrents by means of a fused switch and one by a circuit breaker.

Blasting switches are either built locally in the mine shop, or standard switches are remodeled to provide a short circuit across the lead wires to the blast, with various features to insure the switch being in the "off" of "short-circuited" position when the door is closed and locked. In one instance the short circuit across the lead wires to the blast is grounded (fig. 7, A). Many companies do not consider this a desirable practice, because the "ground" may be at a different potential from a rail, pipe, or other object at the blast, which may result in a flow of current through the electric detonators should one leg wire touch the rail or pipe while the other is being connected to the lead. The writers know of an instance in this district where a difference of potential of 2.3 volts existed between two so-called "grounds".



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All six assemblies include a gap or break (varying from a few inches to 3 feet) in the blasting circuit near the blasting switch. The Bureau believes that the width of this gap should be at least 5 feet to protect against lightning or other high-potential currents. In all but one instance, contact across the gap is made manually; this being the operation that completes the circuit and fires the blast. The exception is the arrangement used by Company A (figs. 1, 2, and 3), where the jumper cable across the gap is first affixed and the blast actually fired by closing the blasting switch. The first arrangement, in which contact across the gap is made manually and will fall out unless held in place, is more positive than the jumper cable referred to above, which can, and is likely to, be left in place unless blasting activities are closely supervised. However, in regard to possible burn hazards, the enclosed-type blasting switch is safer to operate. It should be noted that the blasting switch in this instance requires a ground for protection of the operator, and the grounding of switches on both sides of the lightning gap largely offsets the effectiveness of such gap. To overcome this disadvantage, Company A is considering the inclusion of a grounding conductor in the jumper cable, which will effectively ground the blasting switch when the jumper cable is in place. This appears to be a good practice.

Four types of "safety switches" are used: The signal-type switch shown in figure 2, C, the nonfusible safety switch shown in figure 7, A, the magnetic blasting switch shown in figure 6, C, and the air-operated relay switch shown in figure 7, B. The first two types function as a short circuit across the blasting lead wires, and the last two types actually cause an interruption of both lead wires in the blasting circuit as well as a short circuit. The two latter types are preferred because a simple short circuit across the blasting leads in effect causes the lead wires to function as a single conductor. This may be at a different potential from the ground, track, or a pipe at the face due to a number of causes, such as failure of the insulation on the lead wires or an induced current in the lead wires. For this reason, it is important that long leading wires be sectionalized with one or more "safety switches," and lead wires should be short-circuited at these points.

Two "safety switches" (the magnetic blasting switch and the air-operated relay switch) are operated by remote control. This feature was incorporated to reduce the hazard of a premature blast caused by stray currents in the leading wires at the time the short circuit at this point is removed, and to permit the "safety switch" to be installed closer to the blast. This is an excellent feature; but again, caution must be exercised to see that the switches are in working order. For instance, it is quite probable that the average miner may assume that such a switch is functioning properly rather than take the time to inspect the relatively complex mechanism. In this event, a simpler switch, such as an enclosed two-pole, externally operable safety switch, connected so that the lead wires are interrupted, would be safer.

In five of the six assemblies the blasting current is applied by touching the contacts of a firing handle or plug to live contacts; in the sixth, an enclosed, externally operable switch is closed and, if a direct short circuit occurs, a circuit breaker is tripped. The important feature is that the application of current is momentary to prevent possible kindling of a fire.



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Probably the most controversial point in connection with electric blasting is grounding. This is evident from the disagreement among handbooks and published literature on the subject, as well as in actual practice. Grounding of the various switches described in this report has been indicated. In general, ground connections are eliminated or avoided beyond the switch from where the blast is fired. It is especially important to avoid grounding of the short circuits across the leading wires. Another point frequently overlooked in practice is proper insulation of the leading wires, especially at joints or splices. This is of paramount importance in the protection against stray currents.

All six assemblies are a definite improvement over the usual electric blasting equipment in the average mine in this country. They are the result of a determined effort by safety men and operators to eliminate accidents involving explosives. Progress is still to be made, however, in the standardization, manufacture, and use of electric blasting switches, which will result in a wider use of electric blasting with an attendant increase in safety and efficiency.

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